imaginary double points is clearly zero, which is another verification of previous results. (16) is also true when m_1 is even. Polar and cartesian equations for m_1 even may be established in a similar manner as in (14) and (15).

3. Examples.—When $m_1 = 3$, $2\ k = 4$, the polar and rational parametric equations of the curve[3] are

$$\rho^4 - R\rho^3 \cos 3\theta - \frac{27}{4} R^2\rho^2 + \frac{27}{4} R^4 = 0$$

$$x = \frac{t^4 - 12t^2 + 3}{4\,(1 + t^2)^2},\quad y = \frac{2t\,(3 - 5t^2)}{4\,(1 + t^2)^2};\quad (R = \tfrac{1}{4})$$

When $m_1 = 4$, $2\ k = 6$, cartesian and polar equations of the curve are

$$3(x^2 + y^2)^3 - 24(x^4 + y^4) - 32\ x^2y^2 + 39(x^2 + y^2) - 18 = 0,$$
$$3\ \rho^6 - (2 \cos 4\theta + 22)\rho^4 + 39\rho^2 - 18 = 0.$$

As m and k increase, the construction of the equations with numerical coefficients becomes increasingly difficult.[4]

[1] Greenhill, *Les Fonctions Elliptiques et leurs Applications*, chap. III.

[2] Tannery et Molk, *Eléments de la Théorie des Fonctions Elliptiques*, **4**, pp. 176–192; Appell: *Traité de Mécanique Rationnelle*, **1**, p. 494.

[3] This curve is known and was investigated by G. de Longchamps: *J. Math. Elémentaires*, **4**, 1885, 269–277; also by H. Brocard: *J. Math. Spéciales*, (Ser. 3), **5**, 1891, 56–64.

[4] A curve of this type may be symbolically denoted by $C^{m_1}_{2k}$. Tabulations of all curves, with their real and imaginary double points as far as C^{12}_{22} have been made, also actual graphs of C^3_4, C^6_4, C^5_6. C^5_8.

THE TAXONOMIC POSITION OF THE GENUS ACTINOMYCES

By Charles Drechsler

Cryptogamic Laboratories, Harvard University

Communicated by R. Thaxter, May 14, 1918

To the genus Actinomyces are usually assigned a variety of peculiar and very minute filamentous organisms, widely distributed in nature, concerning the taxonomic relationship of which divergent views have been held. Most of the earlier medical writers, whose attention was centered on forms associated with human and animal diseases, placed the genus with the pleomorphic bacteria. Others recognized conidia in the clavate elements produced by one of these pathogenic forms, *Act. bovis*, within the animal body, and referred this parasite to the Fungi. These elements were later shown to represent degenerative structures; but as subsequent investigations on a number of species, including various saprophytic forms, as well as the common potato scab

organism and several pathogenic types clinically similar to *Act. bovis*, revealed decidedly fungoid characteristics, not only in the profusely branched condition of the vegetative thallus when grown in culture, but also in the production of an aerial mycelium and Oidium-like spores, the view that the genus is to be placed with the Hyphomycetes has continued to receive support.

According to another view which has gained quite wide acceptance, Actinomyces represents an intermediate group and a phylogenetic connection between the Bacteria and the Fungi. It is held that the genus originated either as the result of the development of bacterial forms possessing a tendency toward the branched condition, like the tubercle and the diphtheria organisms; or as the result of the reduction of hyphomycetous types, which, in their ultimate stages, yielded the much simpler true bacteria.

In order to determine the merits of these contending views, the writer subjected a large number of saprophytic species isolated from the soil, air, etc., as well as several virulent strains of the potato scab organism secured from Mr. M. Shapavalov, to morphological study. The results may be summarized as follows:

(1) The vegetative thallus of Actinomyces consists of a mycelium composed of profusely branching hyphae, the terminal growing portions of which are densely filled with protoplasm. Toward the center of the thallus, the vacuoles increase in size, and may be associated with the presence of metachromatic granules; the latter having nothing in common with bacterial endospores or 'micrococci,' for which they were mistaken by early observers.

(2) The vegetative mycelium attains an extent incomparably greater than the branching figures recorded for bacteria of the acid-fast group; and the hyphae lack the uniformity in diameter generally characteristic of the Schizomycetes.

(3) The aerial mycelium produced on suitable substrata by most species, occurs, usually, in the form of a mat of discrete fructifications; but in other species, these fructifications are frequently combined to form numerous peculiar erect Isaroid sporodochia.

(4) In any case, each individual fructification represents a well characterized sporogenous apparatus, consisting of a sterile axial filament bearing branches in an open racemose, or dense capitate arrangement. The primary branches may function directly as sporogenous hyphae, or may proliferate branches of the second and of higher orders; sporogenesis, in the latter case, being confined to the terminal elements, the hyphal portions below points of attachment of branches remaining sterile.

(5) Two tendencies in the development of fructifications are recognizable, one leading to an erect dendroidal type in which successively proliferated fertile elements undergo processes of sporogenesis in continuous sequence; and the other leading to a prostrate, racemose type, in which sporogenesis is delayed in the older branches until the younger branches have also attained their

final extension. The majority of species show these tendencies combined in different ways.

(6) The sporogenous hyphae of most species are coiled in peculiar spirals sometimes resembling the spores of the hyphomycetous genus Helicoön. These spirals exhibit pronounced specific characteristics in the number, diameter, and obliquity of their turns, and especially in the direction of rotation (whether dextrorse or sinistrorse).

(7) Sporogenesis, where it can be followed, begins at the tips of the fertile branches and proceeds basipetally. In the larger number of species the process involves the insertion of septa, which in certain cases, are relatively very massive, and in others, so thin as to be barely discernible. The disposition of these septa while the delimited spores undergo maturation processes, varies with the species: (1) they may remain more or less unaltered; (2) they may suffer a median split, the two resulting halves being then separated as the result of the longitudinal contraction of the young spores, leaving alternate portions of hyphal wall completely evacuated; (3) or they may first become considerably constricted and subsequently converted into non-stainable isthmuses connecting the mature spores. The apparent absence of septa in the sporogenous hyphae of other forms, is, perhaps, attributable to optical difficulties.

(8) Granules are readily differentiated in the spores of many species, which possess the staining properties and uniformity of size characteristic of nuclei; they generally occur singly, but in the larger spores of a few forms, two are often found occupying diagonally opposite positions.

(9) As in the vegetative thallus, metachromatic granules occur in the aerial mycelium, being very rarely found in spores or sporogeneous hyphae but becoming very abundant in degenerate sterile hyphae.

(10) The older axial filaments of some species show marked distensions, which, in extreme cases, result in figures simulating Leptomitus. These arise as local distensions at the points of attachment of the more extensive lateral sporogenous processes. Cuneate modifications of the sterile axial filaments below the origin of branches, also occur.

(11) Curious spherical structures appear regularly in some forms, both in the sterile axial hyphae, where they may contain either a median septum or a number of peripheral metachromatic granules, and in the sporogenous hyphae where they are associated with the regularly spaced septa.

(12) The spores germinate readily in suitable solutions, producing from one to four germ tubes, the approximate number being more or less characteristic of the species.

(13) Owing to the absence of any well defined bacterial characteristics, the writer is of the opinion that the view that Actinomyces represents a transition between the Hyphomycetes and the Schizomycetes, as well as the phylogenetic corollary based upon it, may safely be abandoned. If mere size is to be regarded as important, it would appear to be equally profitable to look

for bacterial affinities in some ascomycetous and sphaeropsidaceous forms, the hyphae of which are similarly very minute. It is doubtful whether far-reaching taxonomic generalizations can be based upon the 'acid-fast' staining reaction, especially as this reaction has not played a very important rôle in mycological research. There seems to be no adequate reason why the genus should not be classed, in an unqualified manner, with the Hyphomycetes, as a Mucedineous group with tendencies toward an erect Isaroid habit.

A more complete illustrated account will appear shortly in the *Botanical Gazette.*

STUDIES OF MAGNITUDES IN STAR CLUSTERS, VIII. A SUMMARY OF RESULTS BEARING ON THE STRUCTURE OF THE SIDEREAL UNIVERSE

By Harlow Shapley

Mount Wilson Solar Observatory, Carnegie Institution of Washington

Communicated by W. S. Adams, May 21, 1918

In the preceding communication of this series[1] methods were discussed for the determination of the relative distances of a considerable number of globular clusters. The methods have now been developed so as to give not only relative values but also fairly reliable absolute distances for all globular clusters, and for all variable stars of the Cepheid class for which periods and apparent magnitudes are known. A rather detailed summary of the procedure, its accuracy, and the results of a thorough application of the methods, has been given in the February issue of the *Publications of the Astronomical Society of the Pacific.* The present note will be confined to a synopsis of the more important results pertaining to the probable extent and arrangement of the sidereal system. The detailed discussion is appearing in a series of papers in the *Astrophysical Journal,* and will be separately published as *Contributions from the Mount Wilson Solar Observatory,* Nos. 151–157.

Extending to the globular clusters the work of Miss Leavitt, Hertzsprung, and Russell on the Cepheid variables of the Small Magellanic Cloud and of the galactic system, we have been able to establish beyond question the interdependence for these variables of absolute luminosity and period of light variation. By combining the apparent and absolute magnitudes, the distances and positions in space have been determined for about 140 Cepheid variables, most of which are much more distant than any objects for which parallaxes have been directly measured. Figure 1 shows their distribution.

The distances of globular clusters are of a different order of magnitude from those heretofore entering stellar investigations. Although the average naked-eye star is near as compared with many Cepheid variables, the most remote Cepheid now known is not so far away as the nearest globular cluster. The